

Oceanographic Variability and the Performance of Passive and Active Sonars in the Philippine Sea

Arthur B .Baggeroer
Center for Ocean Engineering, Dept. of Mechanical Engineering
Massachusetts Institute of Technology
Cambridge, MA 02139
Phone: 617 253 4336 Fax: 617 253 2350 email: abb@boreas.mit.edu
and
Edward K. Scheer
Department of Applied Ocean Physics and Engineering
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone : 508 289 2823 Fax : 508 457 2194 email : escheer@whoi.edu

Award Number: N00014-07-1-0326
<http://acoustics.mit.edu>

LONG TERM GOALS

The title of this project reflects works completed under the NPAL program where long range signals were received by the NPAL billboard array off the coast of California. This effort transitioned to the BASSEX (Basin Acoustic Seabed Scattering Experiment) which was conducted jointly with Scripps Inst. of Oceanography and the Univ. of Washington as part of the SPICEX/ LOAPEX/BASSEX experiments. Last year's annual report discussed results already achieved during BASSEX. This last year we executed the engineering test phase of PhilSeaEX an entirely different type of experiment.

Our long term goals of the PhilSeaEx experiment are to study the forward scattering the base of the water column between the seafloor and immediately above the critical depth. This is often called the RAP path and one of receivers is a so called RAP VLA. The other receiver is at the surface to measure RAP path properties for a source near the surface and a receiver at depth using reciprocity. For this we used the following sources: J15 on loan to SIO, the MP200 and ATOC low frequency acoustic sources from the Univ. of Washington, and the SIO Pentagon sources mounted axially. For receivers we used the ONR FORA (Five Octave Research Array) and 30 elements of future water column spanning array of SIO distributed around the bottom critical depth. At the 75 and 250 Hz center frequencies of the signals transmitted this array has an aperture of 9.6 and 32 wavelengths respectively.

OBJECTIVES

Our long range objectives focus on generating acoustic models appropriate for array signal processing. We long ago postulated a chain of uncertainty for the formulation of

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 2009		2. REPORT TYPE		3. DATES COVERED 00-00-2009 to 00-00-2009	
4. TITLE AND SUBTITLE Oceanographic Variability And The Performance Of Passive And Active Sonars In The Philippine Sea				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Massachusetts Institute of Technology, Center for Ocean Engineering, Dept. of Mechanical Engineering, Cambridge, MA, 02139				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT The title of this project reflects works completed under the NPAL program where long range signals were received by the NPAL billboard array off the coast of California. This effort transitioned to the BASSEX (Basin Acoustic Seabed Scattering Experiment) which was conducted jointly with Scripps Inst. of Oceanography and the Univ. of Washington as part of the SPICEX/ LOAPEX/BASSEX experiments. Last year's annual report discussed results already achieved during BASSEX. This last year we executed the engineering test phase of PhilSeaEX an entirely different type of experiment					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 7	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

algorithms needed for this processing. Here we argue the following: environmental uncertainty leads to acoustic uncertainty then to signal processing uncertainty and finally to command uncertainty based on the output of the displays. We note that BASSEX examined the propagation several convergence zones beyond the seamounts as well as coherent pulses instead of explosives. The long range recordings demonstrated how convergence zones reestablish and one can receive signals in back of the seamount while the coherent signals permit precise measures of travel time. Unfortunately, the FORA array could not be towed below 300 m, so we could not study the ray path structure at depth.

The objective of the Philippine Sea experiment is to measure the acoustic field with a thirty element array for 2008 and 100 element water column spanning for 2009 built by Scripps. The 2008 array spans the bottom critical depth with one half of the hydrophones densely spaced below this depths and the other half with larger spacing above it. This will be augmented with the FOR A towed array which will be towed near the surface so simultaneous bottom and surface measurements are obtained. The objectives are

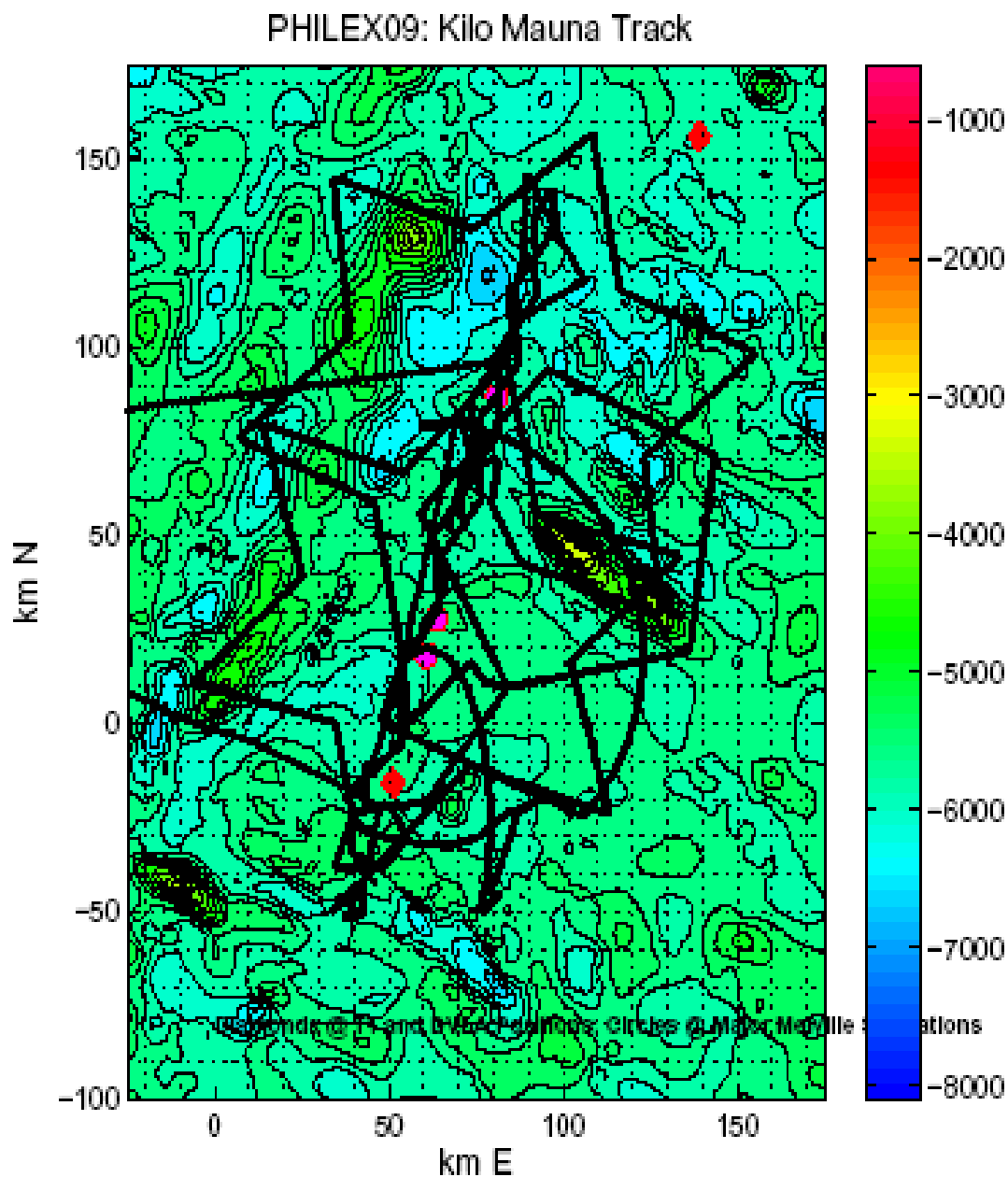
- i) Measure the multipath structure as signals turn at the critical depth;
- ii) Determine the scattering function of beamformed signals with these data;
- iii) Measure the ambient noise near the critical depth to determine the nature of the field during its transition from ducted propagation from long range shipping to near vertical energy below it.

The environment near the ocean bottom in the part of the Pacific for the experiment has a quiet region where the noise is lower than it is above the critical depth (Several measurements on board by David Barclay of SIO supported this) . The geoacoustics has about 50 meters of sediment before encountering the oceanic basalt. Both the sediment and basalt have gradients which will act as an acoustic prism refracting signals according to their spatial frequency. (This phenomenon are often seen in exploration seismics.) Resolving this multipath will be a key objective for the data analysis where we use all combinations of source/receiver geometries.

APPROACH

The approach for the Philippine Sea experiment is formulated in the experiment plans. They emphasize transmissions with an augmented J-15 on radial paths to the DVLA and the FORA array. These are designed to emphasize the transmissions at ½ convergence zone offsets and less to measure signals within the RAP teacup. In addition, one wants to measure the behavior as one transits the RAP “teacup” and several adjacent ones.

One can see this in the track plan for the receiver ship *RV Kilo Moana* relative to the J-15 as well as the MP200 on the *R/V Melville*. We see two hexagonal tracks which are at a radius where they transit the convergence zone. One does not want to run an end on transit as this puts the ship noise in the same beam as the desired signal, so slanted crossing were used. These gave excellent data as the RAP boundaries were crossed. Next, we ran a zig-zag straight lines from two CZ out with the two ship closing and then opening on each other. Again the zig-zag is to put the the ship noise in a beam outside of



the desired reception beams. Finally, we were running a CTD line when an incipient tropical depression cut the cruise short.

Figure 1: Track Plan for the R/V Kilo Moana during the PhilSeaEX experiment (relative positions). Note the hexagonal tracks at approximately $\frac{1}{2}$ CZ and then the zig-zag closing tracks running between the SIO source and SIO DVLA. Also note

the high ridge at approximately 50km N, 110km E which impacted receptions for paths crossing it.

WORK COMPLETED

Two theses on the BASSEX data were completed by Joesph Sikora and Hyun “Joe” Kim. These concern reconciling the BASSEX seamount data and theoretical 3D wave models with particular attention to horizontal refraction. They are liste in the publications section.

The primary work completed was the planning and execution of PhilSeaEx cruise as described in the previous section. This require several planning meeting plus the actual time at sea.

RESULTS

We found that the FORA array still had glitches in the data recording, so much of our time has been spent eliminating these artifacts. We do present some initial results

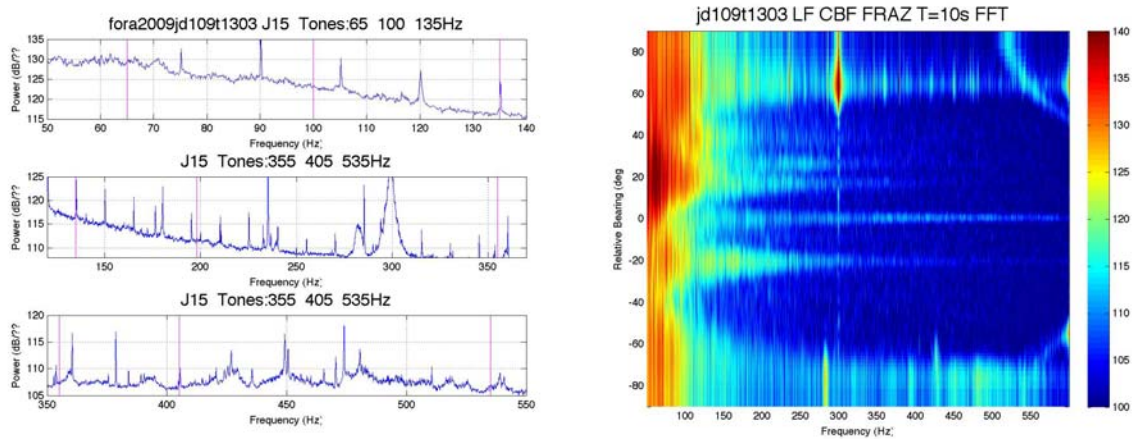


Figure 2a,b: FORA array beam output for a J-15 multitoneal transmission and its FRAZ (Frequency – Azimuth) display covering all beams. Note the large 300 Hz wideband signal in the direction of the J-15 source at 65 degrees. Also note the presence of several discrete tonals only in this beamformed.

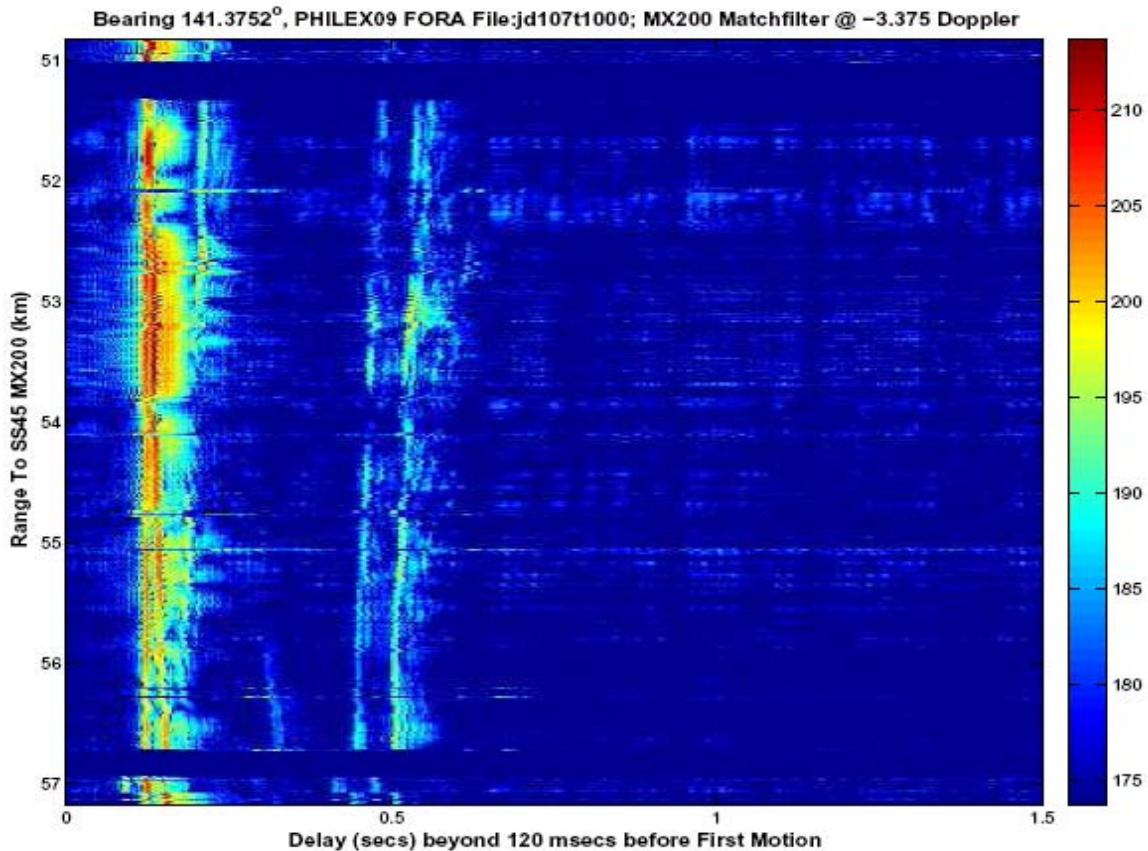


Figure 3: Matched filtered output of the T1000 source over a sequence of transmissions. The returns have been Doppler (or time aligned) by first motion and corrected by -3.375 Hz, or approximately 4.5 kts. Roughly, 6 km were covered by the *RV Kilo Moana* during this interval. The first arrival is a direct with two range dependent multipaths while the second is deeper diving signal again with two paths. There is also evidence of a side echo at approximately 56 km which may be from the nearby seamount. (See Fig 1)

IMPACT

The Philippine Sea Experiment will couple very well to ongoing work for RAP VLA's now being developed by the Navy under N874 sponsorship. The most important part will concern the analysis of the bottom interaction near the base of the DVLA and the convergence zone crossing indicated by tracks in Fig. 1.

TRANSITIONS

None under this program

RELATED PROJECTS

The PI was/is involved with a number of recent ONR projects: These include the SPICEX, LOAPEX and BASSEX Long Range Propagation Experiment (OA), the PLUSINP project (PM: Dr. T. Paluscuwicz, Application of Random Matrices to ASW Signal processing (US) John Tague; and the MURI on acoustic communications.

PUBLICATIONS

- 1) Sikora, J., Sound Propagation around Underwater Seamount, PhD Thesis, Dept. of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, January 2009
- 2) Kim, Hyun J. Forward Sound Propagation around Seamounts: Application of Acoustic Modeals to the Kermit p Roosevelt and Elvis Seamounts, PhD Thesis, Dept. of Mechanical Engineering, Massachusetts Institute of Technology, May 1999

HONORS/AWARDS

IEEE Signal Processing Society Award